

Capturing Uncertainty in the Common Tactical/Environmental Picture

Brian R. La Cour
Applied Research Laboratories
P.O. Box 8029
Austin, TX 78713-8029

phone: (512) 835-3961 fax: (512) 490-4244 email: blacour@arlut.utexas.edu

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LONG-TERM GOALS

The long-term goal of this project is to characterize the uncertainty in active sonar performance due to the environment.

OBJECTIVES

The objectives of this project for FY02 were (1) to identify geographic regions for which active sonar data is available, (2) to develop, in conjunction with Metron Corp., a Bayesian description of target state with which to characterize target state uncertainty, and (3) to compare real-world active sonar data to modeled reverberation from the Applied Physics Laboratory of the University of Washington (APL/UW) and determine the effects of internal waves on the uncertainty of those predictions.

APPROACH

Our institution is part of a larger team headed by APL/UW that includes NRL-SSC, NRL-DC, Metron Corp., and Oregon State University, all funded under the ONR Capturing Uncertainty Departmental Research Initiative (DRI). ARL:UT's role in the project is to provide statistical analysis and signal processing of model data provided by APL/UW and to cast this processed data into a form suitable for implementation in a Bayesian tracker. By varying the environment in a known way, we can study the impact of those variations on sonar performance and detection capability. The statistical description of the data obtained in this manner is used to construct a Bayesian likelihood distribution for the target state, which is used by Metron in its Likelihood Ratio Tracker (LRT). Initially, our focus will be on the effects of internal waves and bottom backscatter on monostatic active sonar returns.

WORK COMPLETED

For the initial phase of the project, we have chosen a time and region of the world to begin modeling corresponding to the SHAREM 134 exercise. This exercise took place in the East China Sea during July and August of 2000 in an area just west of the Ryukyu Trench. This site was chosen both for its tactical relevance and the availability of active sonar data, being also the area of operations for SHAREMs 130 and 138. We have selected a particular planned bottom event involving a diving and resurfacing submarine as the starting point for our investigations.

For the Bayesian tracker we have developed two likelihood descriptions for characterizing uncertainty at both the signal and information processing level. For the latter, a cluster-based likelihood function

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was developed using as its basic measured input the mean position of threshold crossings in a cluster and the number of such clusters, as determined by the Echo Tracker Classifier (ETC) automated active sonar system. For the former, a log-likelihood ratio (LLR) function based on beamformer output and independent model predictions of mean reverberation was developed. Preliminary comparisons suggest the LLR may provide a higher signal-to-noise ratio compared to the standard normalizer used in ETC. (See Figure 1.)

Finally, we have made some preliminary comparisons of model-predicted reverberation including internal wave effects to actual reverberation measurements made at sea during the aforementioned SHAREM 134 exercise. For these predictions, the ray-based Comprehensive Acoustic System Simulation (CASS) program was used. A sample comparison is shown in Figure 2, which involves the transmission of a 200 Hz bandwidth hyperbolic frequency modulated (HFM) pulse.

RESULTS

CASS was found to give reasonable predictions of reverberation levels for the region of interest in the East China Sea. Preliminary results suggest that the impact of variations in the sound speed field due to internal waves contributes a standard deviation in the predicted reverberation levels on the order of 2 dB. In future work we will consider the impact of uncertainty in the bottom characteristics on reverberation and transmission loss predictions. We will also investigate the propagation of this uncertainty into the realm of detection and localization through the incorporation of a Bayesian tracker with ETC.

IMPACT/APPLICATIONS

Results of this work would apply generally to the augmentation of tactical decision aids (TDAs) such as IMAT, SIMAS, SPFSS, STDA, and TCP by incorporating uncertainty estimates of predicted performance. It should also provide the basis for incorporating and displaying uncertainty in target state estimates due to uncertainty in environmental predictions such as propagation loss and sound speed. The specific target is the US Navy's Common Undersea Picture (CUP) Program.

TRANSITIONS

None.

RELATED PROJECTS

1. The **ASIAEX** experiment (<http://www.arl.nus.edu.sg/asiaex/>), performed in the South and East China Seas, has gathered data in a region of the ocean overlapping that of the SHAREM 134 exercise.
2. The **Geologic Clutter Initiative** project aims to study the contribution of subsurface geological features to active sonar clutter.
3. The **North Pacific Acoustic Laboratory (NPAL)** studies the limits the signal processing imposed by variable ocean processes such as internal waves.
4. The **Integrated ASW** project is developing and testing a version of the Likelihood Ratio Tracker (LRT) for use in combining below threshold detections from multiple platforms such as multistatic

active detections from IEER and a DDG to produce improved detection performance. The technology developed in this DRI may be incorporated into this version of LRT for transition.

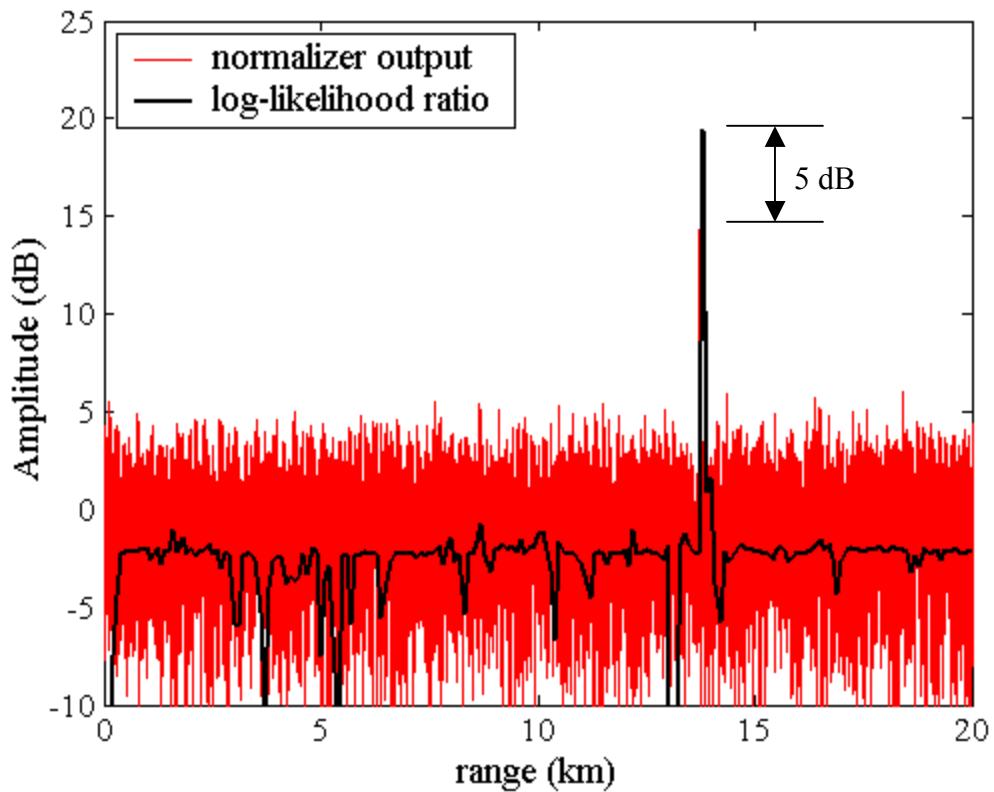


Figure 1: Plot of the time series based log-likelihood ratio versus output from the ETC normalizer. A 5 dB gain is achieved on the target, with significant noise reduction.

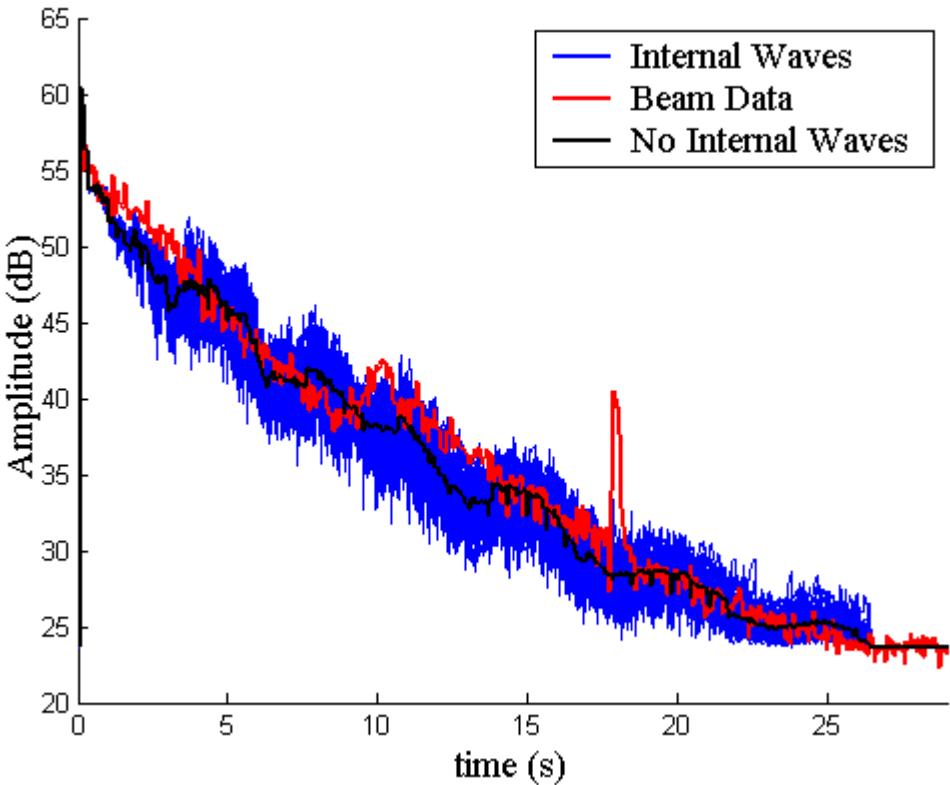


Figure 2: Plot of measured reverberation (red) from beamformer output against the modeled mean level without internal wave effects (black) and with 110 realizations of an internal wave field (blue). The target coincides with the spike at about 18 seconds. The amplitude, in decibels, is relative to an arbitrary reference.